

# Our Digital Future

ANNUAL REPORT 2022



**Improving  
the lives of people  
with disability  
and health pathways**

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**Acting for  
environment**

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**Amplifying  
contemporary  
energy mutations**

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**Innovate for  
education**

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**Using digital  
reliability  
of information  
and services**

*Inria*



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# BRUNO SPORTISSE

## Inria CEO

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### How can we get a sense of perspective within a digital world that is constantly accelerating? How can we successfully meet society's growing expectations on public research in digital?

Given the impact digital is having across society, if we are to remain masters of our fate then public research has serious responsibilities to face up to: digital sovereignty; algorithmic decision-making across all sectors (from health to the workplace); the virtualisation of the world and the possible deconstruction of the physical world; the impact of the digitisation of the world, particularly on young people; challenges for our democracies; developing a sustainable and eco-friendly trajectory for digital, and so on. Dynamics within research and innovation will themselves be transformed with the coming to maturity of Generative AI, which will pose a real challenge to us as scientists in terms of our research practices.

In order for Inria to meet its obligations as France's national institute for research in digital science and technology, then it is more essential than ever that we explore collective dynamics with strategic partners, from leading research universities and other national research bodies to public stakeholders with an interest in the digital dynamic, and companies within the industrial ecosystem at both a French and European level. Inria is committed to consolidating these collective dynamics, as it seeks to remain a world leader at the cutting edge of innovation, in addition to delivering impact and supporting public policy in our capacity as a national research institute.

Everything we do is centred around the project concept, irrespective of what form this takes (220 project teams in collaboration with our partners, Inria Startup Studio projects, pilot projects in support of public initiatives in digital, and so on), our sole aim being to deliver greater impact, whether scientific, technological, industrial or in terms of the dialogue between science, technology and society.

This annual report provides an illustration of the diversity of what made Inria in 2022: supporting and developing this diversity is one of the institute's long-term goals. But this report provides only a brief overview of the wealth of activities within Inria, whether this is through our bustling research centres and their ever closer ties with our partner universities - major players at a regional level in the field of higher education, research and innovation - or through Inria's programmes geared towards promoting a collective dynamic in digital at a national level.

No matter the vector, everything is centred around the talent and the dedication of the women and men responsible for Inria's dynamic, from scientists to research and innovation support staff. 2022 showed once again that this engagement is alive and well.

Happy reading!

***“If we are to meet the growing expectations with regard to public research in digital, then it is more essential than ever that we explore collective dynamics.”***



## HIGHLIGHTS OF 2022

### Large-scale projects, awards and internal organisations... What news marked the year 2022 at Inria?



#### Metavers Report

In February 2022, the minister for the Economy, Finance and Economic Recovery, the minister for Culture and the secretary of State for Digital Transition and Electronic Communications launched an exploratory mission on the development of metavers. Rémi Ronfard, director of research at Inria, is one of the three rapporteurs on this mission, which has set out to provide keys to understanding in order to clarify the debate, seize emerging opportunities, better understand the risks posed by metavers and rally French players around a common horizon.



#### Creation of the digital and environment programme

Headed by Jacques Sainte-Marie, Inria's Digital and Environment programme was created in 2022. Its aim is to support the actions and major projects led by the Institute on the major challenges of digital technology for the environment, as well as to address the environmental impact of digital technology.



#### Launch of the Daniel Bernoulli joint laboratory with AP-HP

The Bernoulli Lab is the result of a partnership signed in December 2020 between Assistance Publique - Hôpitaux de Paris (AP-HP) and Inria, and aims to accelerate research and innovation in digital health.



#### Inria coordinates Adra-e

Since 1 July 2022, Inria has been coordinating and supporting Adra-e, a project funded by the European Commission, with the aim of facilitating synergies between the AI, data and robotics communities.



#### Creation of a Directorate-General for Public Policy Support

Officially created on 1 August 2022 and headed by Sandrine Mazetier, the objectives of the DGD-APP (Directorate General for Public Policy Support) are to amplify the mobilisation of the expertise present in the Institute in support of public policies in digital technology and to increase the effectiveness of public policies through digital technology.



#### Creation of the Lyon Centre

After more than 25 years in Lyon and the creation of 15 project teams, the Institute has officially opened its ninth centre, the "Inria Lyon Centre". This move confirms the Institute's proactive policy of supporting the development of world-class university sites in digital science and technology.



#### New names for Inria centres made official

On 1 November 2022, the Inria Centres changed their names, in line with the dynamic established with the Institute's academic partners to contribute to the development of "major university research sites" in France, with international visibility.



#### Inria's Startup Studio celebrates its 100<sup>th</sup> project

In September 2019, Inria launched its *Startup Studio*, a support scheme dedicated to *Deeptech* project leaders. Three years later, the structure celebrated its 100<sup>th</sup> supported project. This milestone marks a real change of scale for the *Startup Studio*, which was set up to create momentum and estimate the pool of potential project leaders.

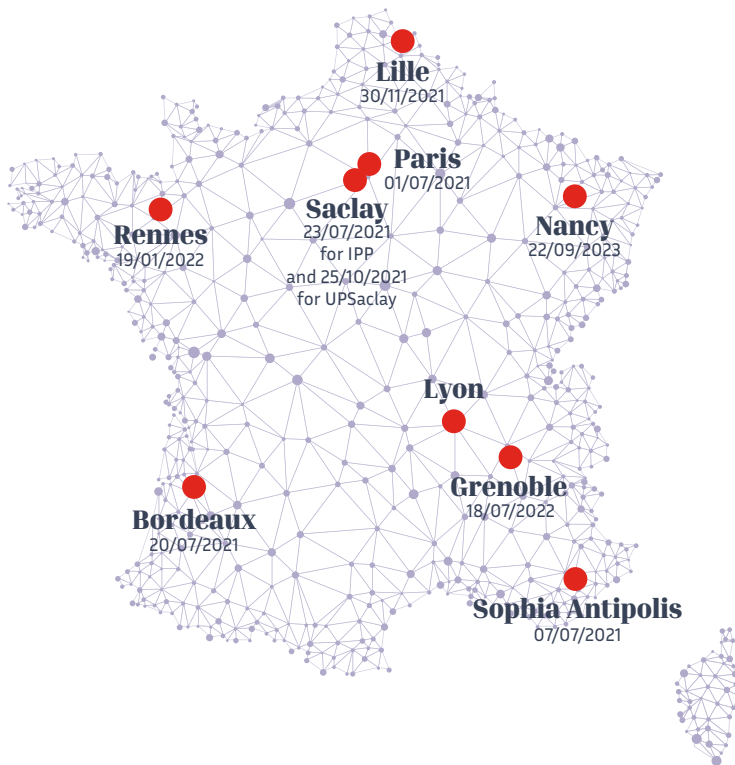


# INRIA'S SITE STRATEGY

Contributing to the development of world-leading university research sites

In 2022 Inria confirmed its commitment to work with its partners towards the development of university sites, in accordance with the 2019-2023 OPC (Objectives and Performance Contract).

## INRIA RESEARCH CENTERS



## ISFPS AND CO-CONSTRUCTION WITH UNIVERSITIES

In 2020 Inria created the "Inria Starting Faculty Position" (ISFP) with the aim of diversifying career opportunities for young researchers. In 2022, 22 scientists were recruited to permanent positions at Inria following a recruitment campaign carried out alongside partner schools and universities, taking into account site priorities for scientific and educational improvement. Personnel recruited to ISFPs have teaching commitments at their universities (32 to 64 hours per year).

## THE BENEFITS OF OUR SITE STRATEGY ON INTERDISCIPLINARITY

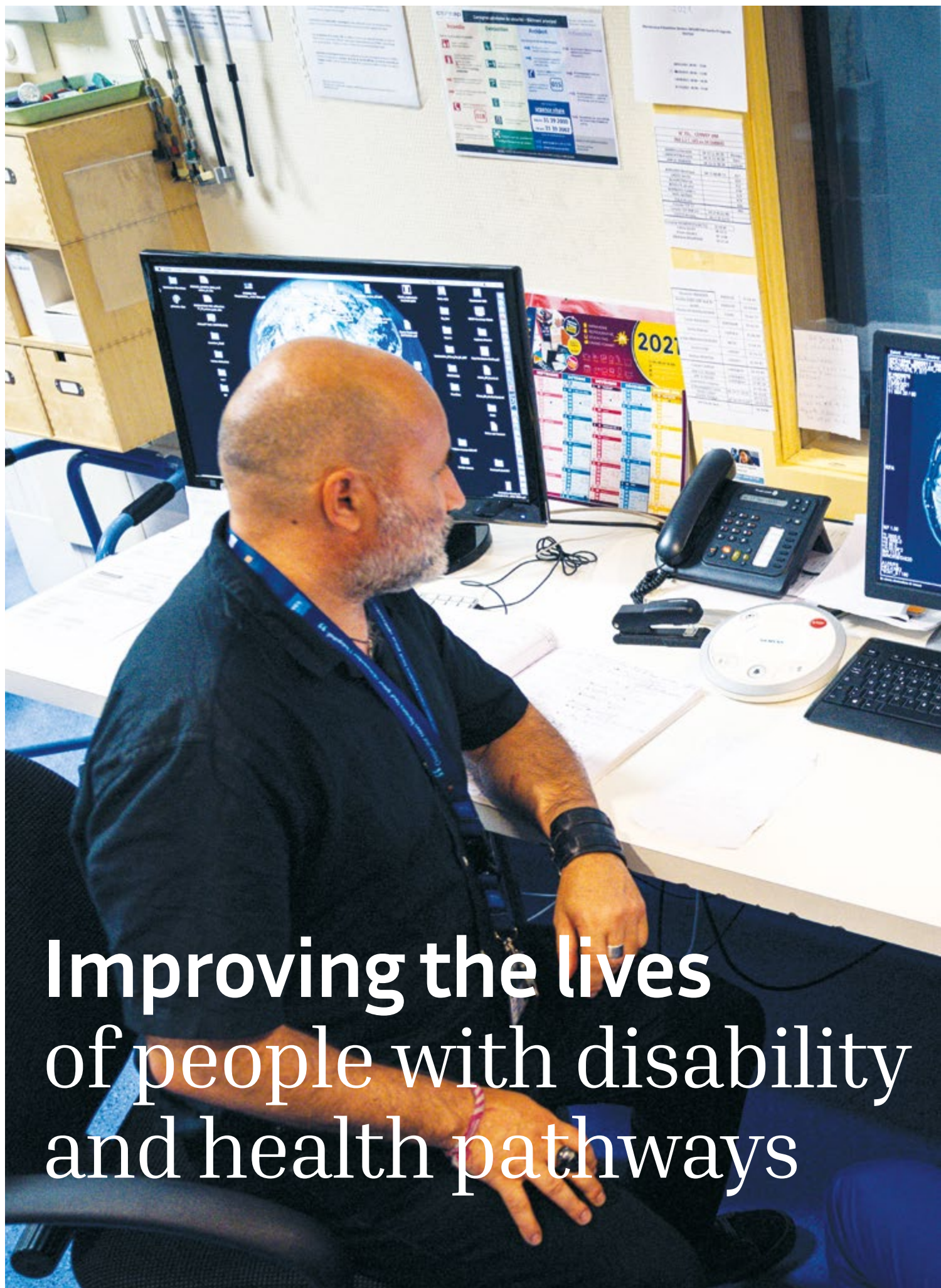
Our partnerships with major multidisciplinary research universities provides a means of increasing the institute's interdisciplinarity, particularly in the "Health and Biomedicine" field, where eight out of every ten Inria publications are produced alongside them (up 25% from four years ago). Today, roughly a third of project teams have at least three journal articles published each year in disciplines other than IT and mathematics.

## OUR DCRS WITHIN LOCAL ECOSYSTEMS

The creation of "University Inria Centres" has given Inria a greater presence within university bodies responsible for designing projects which shape site strategy. In late 2022 Inria was a partner in twelve "ExcellencES" projects across the country, providing digital expertise on a wide range of subjects: research, education, innovation, Europe and international, human resources, campuses and transitions, etc.

## INRIA - COMMITTED TO CO-CONSTRUCTING TRAINING COURSES FOR THE JOBS OF TOMORROW

Inria is joining forces with universities to meet the ambitions of France's national strategy on "the skills and jobs of the future". The target is to have more than 400,000 people trained in digital jobs, with a focus on opening up opportunities for women. The following projects were selected in 2022 alongside Inria: CAP Santé Numérique (University of Bordeaux); EFELIA (3IA network: Côte d'Azur University, Grenoble-Alpes University, PSL); SORBONNE.AI (Sorbonne University); SacIAI-School (Paris-Saclay University).



# Improving the lives of people with disability and health pathways





### Are we seeing the emergence of new trends in digital health research?

**PHILIPPE GESNOUIN,**  
Head of Inria's digital health programme



**What is going to shape the future of digital health? Will research enable major breakthroughs to be made? We caught up with Philippe Gesnouin, head of Inria's digital health programme, to try to get some answers.**

Significant progress has been made in digital health in recent years. We have never had the amount of available information and the processing power that we do today, despite well-documented issues regarding access to data. As a result, we have been able to go further in the development of explanatory and even predictive models of the living world at different levels, in addition to models of organisations and care systems. Launched in partnership with AP-HP (the Paris University Hospital Trust), URGE is a prime example of this.

We are also seeing other really interesting trends starting to emerge, such as the need to work on methodologies for evaluating digital medical devices. This is of crucial importance, particularly seeing as CE marking is set to become mandatory. As a result, we are seeing more dialogue between scientists and stakeholders in the field, particularly in relation to the need to work out how to evaluate devices - most of which are developed by researchers - on a large scale on more restricted, and therefore potentially more diverse, groups. Explainability remains a key consideration, particularly in medicine. Auditability is also important: if a device is faulty, then it has to be possible to audit it in order to work out why and where it went wrong, and who might be to blame. This is something a lot of scientists are currently working on, but we have yet to see any major breakthrough.

Another trend is an effort to break free from the current constraints of machine learning algorithms, which require vast quantities of "clean" data, i.e. data without any errors. In reality, what we have is a lot of "dirty" or unclean data, which could still be used despite having errors and despite being incomplete.

As far as data is concerned, there has been a growing demand for transcriptomic data within research, the goal being to develop methods for RNA seq data analysis in order to get as much information as possible out of it, providing an ever more molecular picture. That said, the methodologies for analysing this data would benefit from greater levels of maturity. I also don't believe we've perfected the hybridisation of this data with other types, such as images, or tabular or categorical data.

Lastly, although there will inevitably be differences between cultures as a result of our different missions, there has been a growing interest in multidisciplinary research, as well as there being more opportunities. Inserm and Inria currently have a number of joint teams, while we have one joint laboratory with AP-HP and another with the Lyon University Hospital Trust. That's before we get on to all of the collaborations between teams from Inria research centres and regional university hospitals. The rise in healthcare data warehouses is also forcing us to reflect on how we might promote the sharing of best practice and tools to make life easier for researchers. The work being carried out by our colleagues on federated learning could also play a part in this.

***"Although there will inevitably be differences between cultures as a result of our different missions, there has been a growing interest in multidisciplinary research, as well as there being more opportunities."***



## OUR ACHIEVEMENTS 2022

### IMPROVING HEARING THROUGH AI

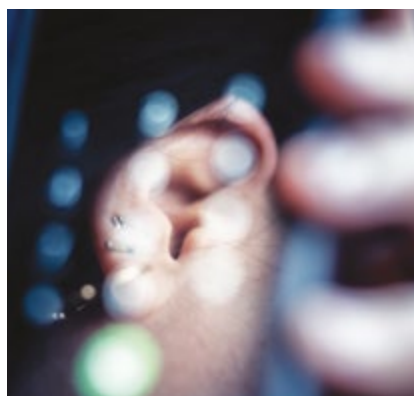
*For people with hearing impairment as a result of auditory neuropathy, which makes it difficult to distinguish between competing sound sources, hearing aids rarely have much of an effect. Seeking to address this, l'Institut de l'Audition (The Hearing Institute), the project team Multispeech (a joint undertaking between Inria and Loria) and CEA List put together a French National Research Agency (ANR) project, Refined.*

*The aim of this project is to precisely identify deficiencies linked to auditory neuropathy and develop AI algorithms capable of separating auditory sources and denoising them. These algorithms will then be incorporated into portable hearing aids.*



### TACKLING RARE NEUROLOGICAL DISEASES

Unity is strength - especially with complementary skill sets. This was the thinking behind the decision by Inria, Claude Bernard Lyon 1 University, the Lyon University Hospital Trust and the biopharmaceutical company *Theranexus* to join forces to create *Alstro-Sight*, a public-private project team. Their aim is to help to identify potential therapeutic targets against rare neurological diseases through a combination of biomedical data, artificial intelligence and digital simulation. Launched in January 2023, the project is set to run for an initial period of four years.



### RESTORING THE ABILITY TO GRIP AMONG PEOPLE SUFFERING FROM TETRAPLEGIA

Two Inria project teams - Willow (Inria Centre Paris and the Computer Science Department at the ENS), which specialises in artificial vision and robotics, and Camin (Côte d'Azur University Inria Centre), which specialises in assistive technology and biomechanics - have set themselves the target of developing technology that will enable people with tetraplegia to grip objects. Their idea is to use a video stream to recreate the position and the shape of the object on a computer, as well as the position and the configuration of the person's hand in real-time. This information, coupled with a biomechanical model of an arm and a hand, will then be used to control an epineural electrostimulation system implanted in the person's arm, enabling them to grip the desired object.



REFINED

ALSTROSIGHT

DISABILITIES

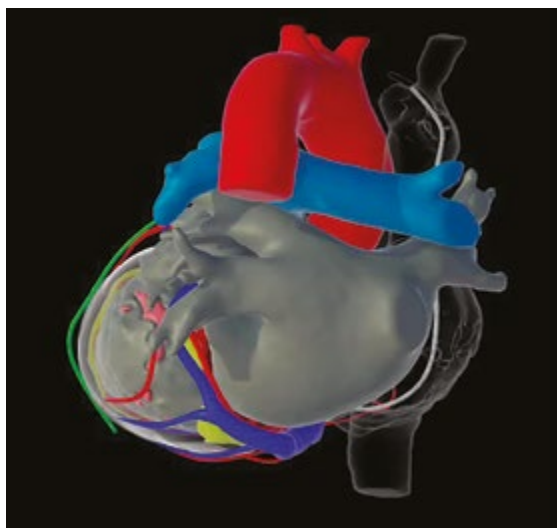


## STREAMLINING PATIENT VISITS TO A&E

How can patient visits to A&E be optimised? "By combining data analysis and digital simulation" is the response from researchers at the Daniel Bernoulli laboratory, a joint undertaking between AP-HP (the Paris University Hospital Trust) and Inria that was set up in late 2020. The URGE project draws on information gathered from AP-HP A&E departments, the goal being to develop a tool for simulating flows in A&E departments. This will then make it possible to test out different systems, fixes and solutions aimed at improving patient care.

## MODELLING HEARTS TO PREVENT CARDIAC ARREST

In response to the 50,000 deaths caused by cardiac arrhythmia each year in France, the Bordeaux university hospital institute Liryc and Inria joined forces to create InHEART. The aim of this startup is to provide cardiologists with virtual models of the hearts of their patients with cardiac arrhythmia using medical imaging. InHEART has just passed the clinical trial stage, moving one step further towards their virtual heart being used in hospitals. inEurHeart is the name of an EU consortium that was set up to evaluate the added value of the digital tools developed by the startup during heart surgery and to demonstrate their effectiveness.



## MODELLING CELL BEHAVIOUR

In late 2022 Jakob Ruess, a researcher with the Lifeware project team at the Inria Saclay Centre, picked up a prestigious ERC Starting Grant. This five-year EU grant will enable Ruess to put together a team for an innovative topic: exploring and creating mathematical models of interactions between intracellular processes and cell population dynamics. His project, Bridging-Scales, has its sights set on applications in biotechnology, including optimising the production of chemical compounds by cell populations.







## OUR INITIATIVES

### The Disabilities Plan steps up a gear

Since 2019 Inria has sought to lead by example on the issue of disabilities, both in terms of the societal impact of its research and in its capacity as an employer. Now, the initiatives they have introduced are starting to bear fruit.



In 2018 only 1.89% of people directly employed by Inria had a disability, some way short of the 6% required by the law passed in 2015. In response, in 2019 the institute brought in a proactive policy in the form of its Disabilities Plan, with three key objectives: to increase the societal impact of research on disabilities, which more than twenty Inria project teams are working on; to improve the recruitment and retention of people with disabilities; and to make Inria an example for digital accessibility.

#### RECRUITMENT AND FUNDING

In order to meet these goals, both human and financial resources would be required. For the first objective, Aurélie Moizo was taken on full-time in October 2020 as a disabilities task officer. She is responsible for coordinating the network of disabilities correspondents: found in every centre, it is their job to provide day-to-day support to people with disabilities, the goal being to promote retention. As far as financial resources are concerned, a first agreement was signed in 2021 with the FIPHFP (a fund to promote the recruitment of people with disabilities in the civil service) for €60,000, which was then succeeded by a three-year agreement worth €260,000 for the period 2022-2024. Meanwhile, the internal budget for the retention of employees with disabilities was increased from €90,000 in 2019 to €150,000 in 2022, providing the resources for a range of initiatives.

#### TRAINING, AWARENESS-RAISING AND ACCESSIBILITY

The list is long, but a few examples are enough to give you an idea of its diversity. There have been recruitment campaigns targeting people with disabilities, accompanied by training for local HR managers. Thirteen new recruits came on board in 2022, while seven employees had their disabilities recognised.

There were also 17 awareness-raising initiatives within centres (including talks, events and escape games) during European Disability Employment Week.

A “digital accessibility” taskforce was created within the IT department in 2022, in addition to a network of user testers made up of Inria employees with disabilities. “As a result, we have seen clear and constant progression”, says Aurélie Moizo. “We have doubled our direct employment rate, but we must continue our efforts if we are to reach the target of 6%.”



A person with curly hair, wearing a striped shirt and dark pants, stands in front of a large digital screen. The screen displays a 3D visualization of a landscape, possibly a river or a large body of water, with a textured, rocky or sandy bottom. The person is looking at the screen and has their hands near the bottom edge, possibly interacting with the display. The screen has a greenish-yellow tint. At the bottom of the screen, there is a small text label that reads "Form Browser".

# Acting for environment



# DECODING

## How research is changing in response to environmental challenges?

**ANNE VARET**, Scientific Director,  
Executive Vice President Foresight and Research ADEME



The ecological transition is something that concerns us all. For a number of years, ADEME has been taking steps to support the research sector, including assisting with the Labos 1.5 initiative, and contributing to the sustainable development and social responsibility label. Although the digital transition is a powerful driver when it comes to tackling the environmental challenges ahead, it also has impacts of its own, lending particular significance to the partnership between ADEME and Inria.

If we are to identify effective ways of driving forward the ecological transition through digital, then we will first need to develop a better understanding of the impact of new technology in terms of the consumption of energy and resources and greenhouse gas emissions. R&D work is underway on methods and references aimed at expanding knowledge of how to assess the environmental impact of digital, but more will need to be done to promote eco-design and digital sobriety. This is one of the targets of the France 2030 Digital Responsibility Strategy and the framework agreement for R&D collaboration between the ADEME and Inria, which includes joint PhD supervision.

Educating people about these challenges is a priority. Alt-Impact, a programme run by ADEME, the CNRS and Inria, was set up to provide training on digital sufficiency. This involves the use of a training platform, a database and methodologies for assisting with the evaluation of digital's impact. The yearly carbon footprint for the consumption of digital goods and services in France is still only a small part of France's overall carbon footprint, but this could triple by 2050 if we do nothing about it. It is time for all of us to take action.

**JACQUES SAINTE-MARIE**, Head  
of Inria's 'digital and the environment' programme



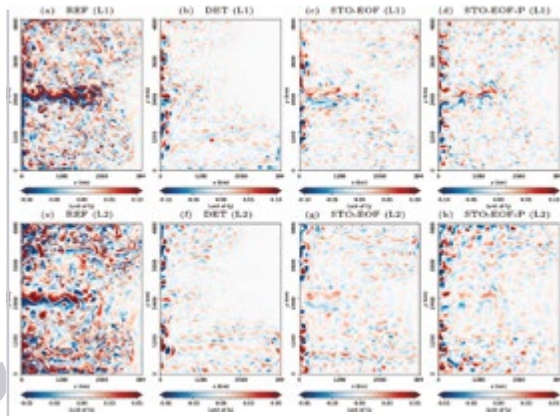
As is the case with many research institutes, Inria is fully aware of the environmental challenges facing us. This has had a range of consequences, from new research subjects and topic mobility to scientific outreach. There are three aspects to this that I would like to draw particular attention to: engagement, meaning and time.

Let's start with engagement. As many studies have shown (such as the barometer on social representations of climate change carried out by ADEME), the environment has become a major consideration within society, and scientists are no exception to this. But this isn't always reflected at a practical level as environmental concerns often clash with people's habits, resistance to change, and scientific recognition in a given field. At Inria we want to make it easier for scientists to take action on the environment, in addition to promoting partnerships with major stakeholders (such as ADEME, INRAE, and so on), encouraging risk-taking and attracting young people. The overarching objective is to influence ongoing changes.

We must give meaning to our research if it is to make an effective contribution to progress, something that is essential despite often being called into question. For a number of years there has been a growing need for meaning in research topics and in scientists' aspirations to contribute towards environmental and social change.

Finally, the consequences of climate change, from those that are visible to those that are forecast, will require extensive and rapid change in a range of sectors, including agriculture, transport and industry. Scientific research may be all about the long-term, but it cannot ignore this time constraint and must tackle the challenges at hand. Fortunately, there are so many ways to contribute and make an impact.





## AN ODYSSEY TO MODEL THE OCEANS

When it comes to studying ocean dynamics, something that is essential to predicting and understanding the climate, scientists currently have to choose between imprecise models covering large areas, and high-resolution models covering small areas. Given the chaotic nature of the subject matter, a level of uncertainty is unavoidable in either case. Producing accurate and reliable models on a large scale requires a combination of mathematics, learning and data assimilation. This is precisely what Odyssey, a joint team created in September 2022 by the Ifremer, IMT Atlantique, Bretagne Occidentale University, the University of Rennes and Inria, has its sights set on.

## A COLLABORATIVE TOOL FOR FARMERS AND GARDENERS

*Sequential Recommendation for sustainable gardening (SR4SG)* is the name of the exploratory action which Odalric-Ambrym Maillard, research fellow with the Scool project team at the University of Lille Inria centre, began leading in 2019. The aim of this exploratory action was to develop a collaborative tool for collecting agricultural data, which it was hoped would help good practices to emerge, in addition to providing users, whether farmers or gardeners, with personalised recommendations. This was no mean feat given all of the parameters to factor in, but in 2023 SR4G culminated in the launch of software development.





## INRAE AND INRIA STILL IN LOCKSTEP

*Inria and Inrae first started working together in the field of digital agriculture back in 2005, and the partnership continues to grow stronger. They already have five joint project teams (Biocore, Mosaic, Graphik, Pléiade and MUSCA) in this area and in mid-2022 signed a new four-year partnership agreement. Not only are they seeking to continue the existing partnerships, most notably in the field of digital biology, but they are also keen to strengthen them and develop new ones, exploring issues such as agricultural practices, the prevention and management of environmental risks, and the development of participatory tools.*

## THE CHALLENGES OF DIGITAL AGRICULTURE

After focusing for so long on yields, agriculture is experiencing its own ecological transition as it seeks to adapt to current issues relating to the environment, ethics and food security. Through its capacity to provide data on crops (through connected objects, smartphones, and so on), transfer it (IoT networks, 5G/6G, wired networks, etc.), store it (in the cloud, for example) and process it (including using artificial intelligence) in order to extract, reproduce and share knowledge, digital has huge potential to assist with this transformation. INRAE and Inria will be working together to identify all of the challenges and opportunities linked to the use of digital in agriculture, while remaining aware of the risks.





## OUR INITIATIVES

### SEnS workshops: group discussions on the relationship between science and society

Launched by two Inria researchers, “Sciences, Environment and Society” (SEnS) workshops give people working in higher education and research an opportunity to discuss, debate and reflect on the environmental and societal implications of scientific research.



**SOPHIE QUINTON**

In what ways does science contribute to building a world that is in keeping with the values of the people driving it forwards? Faced with the climate emergency, an awareness of the societal impact of digital technology (including data, algorithms, artificial intelligence, and so on) and its environmental consequences (consumption of resources, greenhouse gas emissions and pollution), there is a growing desire on the part of scientists to question the relationship science has with society.

Sophie Quinton and Éric Tannier - both Inria researchers, in computer science and mathematics respectively - created the SEnS workshops with support from philosophers of science, experts in collective intelligence, and their colleagues. The aim was to build a forum for dialogue between peers in order to explore the consequences of scientific research, to understand the values science is produced with, and to work together to consider these subjects with a focus on intersectionality and foresight.

#### PROVIDING THE TOOLS FOR DEEPER EXPLORATION

As Éric Tannier and Sophie Quinton explain, “properly understanding all of the ins and outs of these issues calls on a range of disciplines (history, economics, law, philosophy, sociology, politics, ethics, and so on), which most scientists don’t have a background in.” Bringing together around fifteen or so participants for one day, SEnS workshops present an opportunity to hold constructive discussions on potentially contentious topics, and provide the resources needed to explore questions in greater detail.



**ÉRIC TANNIER**

Open to everyone working in higher education and research (including outreach services, technology transfer, and so on), the workshops are held in four sequences. Participants are given the chance to talk about their background and values within their profession, and to consider long-term changes in their research.

#### DEVELOPING A “SCIENCE COMMONS”

*“These workshops are an opportunity to discuss key questions - for instance, is there certain knowledge which we ought not to produce? Are we responsible for the way in which the results of our research are used? - drawing chiefly on short texts written by researchers in the human and social sciences. The objective is to develop a “science commons”, while acknowledging different points of view.”*

Since the first editions at the Inria sites in Grenoble and Lyon in 2021, around fifty or so SEnS workshops have been held, both within the Institute and elsewhere. Aware of the high interest levels, the organisers are already looking ahead to the future: “We’re hoping to have a snowball effect, and for different collectives to adopt this approach and tailor it to their own contexts.”





A man with glasses and a patterned shirt is working at a desk. He is holding a multimeter in his right hand and a red wire in his left. A laptop is open in front of him, displaying a webpage with a red lightning bolt logo and the text "Power API". The background is a blurred office setting with a white wall and a green plant.

# Amplifying contemporary energy mutations





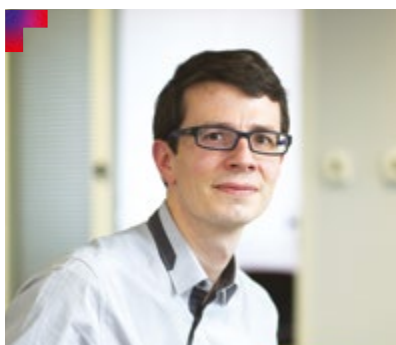
## DECODING

**What are the most promising examples of research into ways in which digital could help support the energy transition?**

**Digital is currently responsible for just 2.5% of France's carbon footprint, but the sector has a vital role to play in the environmental and energy transition. We caught up with Romain Rouvoy, member of the Inria project team Spirals, and Paul Benoit, CEO of Qarnot Computing, to find out more.**

### ROMAIN ROUVOY,

Researcher in the Inria project team Spirals



Aside from issues such as reducing the energy consumption of hardware and software infrastructure, a more systemic approach will involve conducting a multi-criteria analysis of this impact, exploring facets such as the water consumption needed for both the direct and indirect cooling of components which are in continuous use.

A number of solutions are starting to emerge, including the digital boilers developed by Qarnot Computing, who have come up with an original solution for reusing heat emissions from digital infrastructure. Seeking to limit the negative impact of such technology, Qarnot Computing joined forces with Inria - with the support of the Ademe - to assess the impact of both the software and the hardware dimensions of the technology (QBx) and to promote virtuous solutions for the reuse of emissions from the high-performance computers at the Qarnot platform. PULSE is a challenge aimed at raising awareness across the entire value chain of the computing ecosystem (including computing consumers, platform suppliers and consumers of emissions), explaining the tensions between the constraints of performance, cost and impact.

PULSE also seeks to address the waste of resources, developing innovative solutions that will drastically improve efficiency when it comes to the sequencing, running and storage of computing tasks and their results. The tracking of the consumption, energy efficiency and emissions of computing employs the use of PowerAPI, freeware developed by the Inria project team Spirals.

### PAUL BENOIT,

CEO of Qarnot Computing



High-performance computing is wonderful, but is one of the most energy-intensive activities in the digital sphere. Without alternative, radically different solutions when it comes to the consumption of resources, we're headed for disaster.

A number of avenues are currently being explored by the research and industrial communities, seeking to strike the right balance between digital development and low energy consumption. A lot of work is being done at the moment to analyse the full life cycle of products and services, the goal being to identify what pressure they have on resources and the environment. You don't hear a lot about software, but it helps to prolong the life cycle of equipment. With high-performance computing, old machines can be used, even if their output is not as good.

Another interesting aspect is the democratisation of processing power, chiefly through open-source software communities, which is helping to make processing power easier to deploy and more accessible to the general public. The centralisation of data is another key topic of discussion. Since the end of the Second World War we have switched between centralisation and decentralisation, but environmental considerations have shifted the landscape.

Finally, more and more data centres are now trying to reuse their heat, but they lack the tools needed for this. An increasing number of data centres are being built with the reuse of heat in mind - it's built in to the design, and is becoming standard.

Both ourselves and Qarnot had anticipated all of these developments. Our goal is to continue to develop processing power, while reducing its impact. Basically, we want to do twice as much using half as much energy. This is paving the way for us to combine IT needs with heat-production needs, which is good sense, as we are always going to need heating and hot water.

## OUR ACHIEVEMENTS 2022



### PULSE: AN ENVIRONMENTAL INRIA CHALLENGE

Because computer servers produce heat when they are running, this means that they require cooling. Not only does this generate additional energy consumption, but most of the heat produced is lost. As a possible solution to this, Qarnot Computing came up with the idea of recovering the heat generated by high-performance computing infrastructure for use in heating or for hot water in the buildings they're housed in. In 2022 the company undertook a joint challenge with Inria, *PULSE (PUshing Low-carbon Services towards the Edge)*, the aim of which is to determine the exact environmental impact of high-performance computing, before identifying innovative solutions for reducing it as much as possible. One way of doing this is to use energy from processing tasks to supply hot water. Six Inria teams across five sites are involved in this project.

HEAT

### SCANNING APPLICATIONS WITH DENERGIUM

DENERGIUM is a startup that was launched in early 2023 by Hervé Mathieu, who was head of Experimentation and Development at the University of Bordeaux Inria Centre from 2009 to 2020. DENERGIUM has developed the software suite EnergyScopium, which can be used to measure the energy profile of different applications. This makes it possible to measure an application's energy usage, its CO2 equivalent emissions and its usage cost, all in real-time, providing an indication of how efficient it is. The "Optimize" version, meanwhile, is targeted at developers, enabling them to visualise the energy performance of their codes and to concentrate on those which require optimisation. This solution will help to reduce energy usage, without any drop in performance.



### MEASURING SOFTWARE ENERGY CONSUMPTION WITH POWERAPI

How can you find out how much energy a software program or website is actually using? With PowerAPI, a toolkit developed by the Spirals project team at the University of Lille Inria Centre, it's easy - with no need for a watt meter. All you need to do is to enter the specifications of the material components used by your software program or website, and the toolkit will then estimate their levels of consumption using mathematical formulas.

But the researchers are not planning on stopping there: to make PowerAPI even easier to use, they are considering introducing a way of automatically detecting the equipment used and its specifications, in addition to a way of estimating new indicators which could be of use to data centres. Their overarching objective is to give software and website developers and data centre administrators a more accurate picture of how much energy their processes are using, thereby encouraging them to be more economical.



ELECTRICITY





## TAKING BETTER CARE OF THE PLANET THROUGH MODELLING

*When it comes to developing innovations, nothing is more effective than being able to test them out on digital models. In the field of environmental preservation, this is what the Biocore project team, a joint undertaking involving the Côte d'Azur University Inria Centre, the Inrae (sites in Sophia Antipolis and LBE Narbonne) and Sorbonne University/CNRS - Villefranche-sur-Mer Oceanographic Observatory, is seeking to do. Their activities consist of designing and modelling artificial systems, such as those designed to clean up the production of food crops or to transform waste into biofuel. With regard to energy, they test CO<sub>2</sub> fixation systems for producing microalgae for energy purposes.*

## TERRIFLUX - A STARTUP MAPPING FLOWS OF MATERIALS IN DIFFERENT SECTORS

*Bringing part of the economy back to France is now seen as a necessity if we are to achieve the objective of a sustainable economy in a world with finite resources. Doing so will require in-depth knowledge of the flows of materials involved within different processes, but unfortunately, as things currently stand, such knowledge almost always comes at a cost. It was in response to this that the startup Terriflux was launched, providing decision-support tools and services for representing, modelling and creating scenarios of the flows of materials in different sectors (including agriculture, forestry, waste and others), from production to consumption. Its founder, Julien Alapetite, was given dedicated support through Inria Startup Studio, after more than ten years working with the STEEP project team (which stands for "Soutenabilité, transition, environnement, économie biophysique et politiques locales", or "Sustainability, transition, the environment, the biophysical economy and local policy") at the Grenoble-Rhône-Alpes Inria Centre.*

## FRUGALCLOUD: REDUCING THE ENVIRONMENTAL IMPACT OF THE CLOUD

*How can the major digital infrastructure (including data centres) which the cloud relies on meet the challenges of energy efficiency and digital sobriety? Inria and OVHcloud decided to come together to address this major issue through FrugalCloud. The aim of this challenge, which brings together five Inria project teams (Avalon, Inocs, Myriads, Spirals and Stack), is to explore new solutions for designing more energy-efficient cloud services with a reduced environmental impact. Three areas of research will be studied as part of this joint project: software eco-design for services and cloud applications, drivers of efficiency; plus impact reduction and support for cloud users. Work will be divided up among seven sub-projects, most of which will link two Inria teams with one or more teams from OVHcloud, the goal being to carry out an in-depth exploration of possible ways of reducing the cloud's environmental impact. This challenge is being coordinated jointly by Laurent Lefevre (from the Avalon project team) and German Masse (OVHcloud).*







## OUR INITIATIVES

### Energy: Inria continues to economise

In autumn 2022 Inria devised an energy sobriety plan aimed at reducing energy consumption by 10%. The measures that have been applied should enable this target to be met.



When the French government presented its energy sobriety plan in early October 2022, Inria was ready for it. Having already devised its own environment plan in 2020, all that was left for the institute to do was to focus on the specific issue of saving energy. An internal energy sobriety plan was launched last autumn, the aim being to reduce energy consumption by 10%. Three sectors of activity were identified: digital services, buildings and business trips. This makes sense when considering that, out of the 18 GWh/year that is directly consumed by the institute, more than half goes on data centres, and the rest goes on buildings.

#### METHODS WHICH QUICKLY PROVED EFFECTIVE

For the first of these, a study carried out in September-October 2022 identified high-impact items and the actions that would be required in order to address them. The setpoint temperature for server rooms was increased from 20°C to 24°C, enabling a number of cooling units to be switched off. The IT department also switched off 140 machines that had been left switched on despite “barely ever” being used. As for computer equipment, these have been modified so that they only switch on when processing, switching off immediately afterwards.

For buildings, in addition to the heating temperature being reduced to the required 19°C, funds have been released to continue the energy retrofitting work launched within Inria centres following the environment plan (including optimising lighting, installing heat pumps, and so on).

***“An internal energy sobriety plan was launched last autumn, the aim being to reduce energy consumption by 10%.”***

#### DATA STILL TO BE CONSOLIDATED, BUT ENCOURAGING

Finally, with regard to business trips, raising awareness among staff has continued, in keeping with the current policy. This has involved cutting back on flights, and promoting economy class travel (*Flyess guide*). Inria is currently seeking to organise travel data in order to provide researchers with a tool that will show them their CO<sub>2</sub> emissions.

The data from all of these initiatives will still need to be consolidated before the reduction of consumption can objectively be measured. This will be accompanied by the gradual roll-out of sub-metering, the aim being to continue the downward trend. As things currently stand, it should not be too difficult to reach the 10% target.





Innovate  
for education







## The four pillars of research in AI for education

**Artificial intelligence is revolutionising the way we design learning experiences and assess pupils. But what are the keys to the development and integration of this technology in education?**

**We caught up with Jill-Jênn Vie, research fellow with the Soda project team at the Inria Saclay centre, to get some answers.**

### JILL-JÊNN VIE,

Researcher in the Soda project team  
at the Inria Saclay centre



**Artificial intelligence is revolutionising the way we design learning experiences and assess pupils. But what are the keys to the development and integration of this technology in education? We caught up with Jill-Jênn Vie, research fellow with the Soda project team at the Inria Saclay centre, to get some answers.**

Artificial intelligence is currently used in all sorts of ways at different levels within education. By providing users with a personalised learning experience, it has the capacity to improve how pupils learn, how teachers work and, more broadly, what the future of education might look like. But if artificial intelligence is to play a central role in the educational experience of the future then there are four main challenges - all closely linked - which stakeholders in the field must focus on.

The first concerns fairness, confidentiality and transparency in decision-making. AI algorithms learn based on data. If this data is biased in favour of one particular ethnicity, gender or socioeconomic group then decisions - on things such as admissions, for example - may be as well. Care must therefore be taken to ensure that AI algorithms do not amplify existing bias, but rather help to reduce inequality. Many stakeholders have sought to adhere to the French data protection authority's principle of data minimisation, and to exclude the gender variable in their AI systems. At the same time, we need to be able to measure discrimination if we are to tackle inequality. And if an algorithm, or a decision, is not open, then it will be harder to tell whether or not it's creating discrimination.

The second challenge is linked to identifying useful metrics for both teachers and pupils, what is known as learning analytics, e.g. measuring pupils' learning gains. One aspect of this involves summarising and visualising extremely large datasets. The goal here is to summarise the objective functions that will then be optimised, using machine learning, and to provide learners with feedback so that they know where they are within the learning space and what progress they are making.

The third challenge, linked to the previous one, concerns predicting pupils' performance, in order, for example, to identify students who might be struggling and ways in which teaching might be tailored to meet their needs. As they say at the French Department of Education's Scientific Council, we are really good at saying that "the level is dropping", but what we want to know is, "what can we do to address that?". The goal is to be able to act pre-emptively, optimising sequences of exercises presented to pupils (if questions are too easy then the learner will get bored; if they are too hard then the learner will lose motivation) while taking care not to make things worse. This draws on the use of causal inference and reinforcement learning.

The fourth challenge relates to the development of automated content generation: from writing and exercises to corrections. We've heard a great deal about ChatGPT recently. There is a lot of concern within education about how learners might use this to cheat, but it presents a great opportunity to generate fun, innovative exercises that can be tailored to pupils' needs; or for learning a language through interaction with a large language model (LLM) which adapts to the level students are at and provides feedback on any mistakes they might make.

We often focus on the risks, without considering the potential benefits of AI in education and training.



### ROBOTS FOR CHILDREN WITH AUTISM

In 2019 a small American robot called *Cozmo* made its first appearance in two classes in the Nancy-Metz area which specialise in teaching children with autism spectrum disorder. The robot was brought in as an educational tool for the children to promote social inclusion, but also as a research topic for scientists from the Larsen project team, a joint undertaking involving the Inria Nancy - Grand-Est Centre and Loria. One of their areas of focus is what impact interacting with a robot can have on the behaviour of children with autism. *Cozmo* will be staying at the school for a while yet.

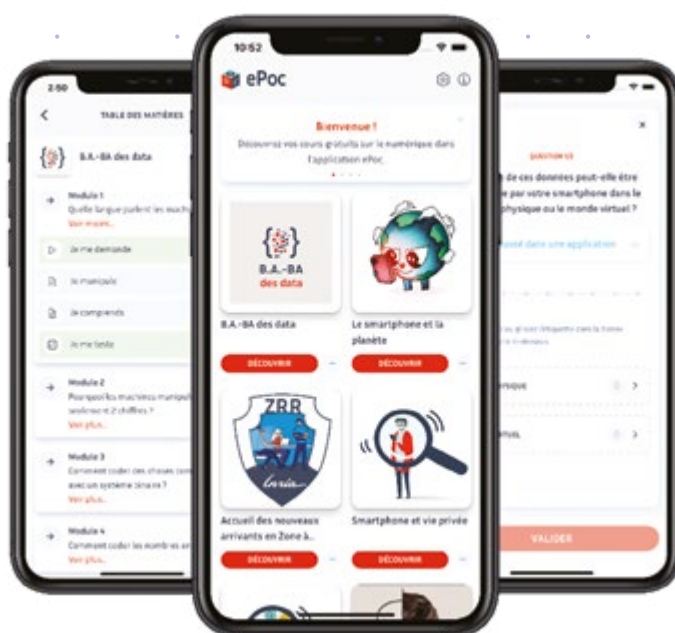
### HELPING PUPILS TO CATCH UP USING AI

*MathFlow* (formerly *Axiome*) is a startup that is seeking to use AI to identify secondary school pupils who are struggling with maths and to help them to catch up. The founder of the startup was given support from Startup Studio to develop a fun mobile application featuring an ITS (intelligent tutoring system) with the capacity to evaluate pupils using adaptive tests and to recommend personalised learning pathways tailored to meet their needs.



### ePOC: DIGITAL LEARNING IN YOUR HAND

*ePoc* (Electronic Pocket Open Course) gives people access to free classes on digital via their mobile devices. Developed by Inria Learning Lab, this mobile application features a number of modules put together by science experts on topics such as data, the Internet of Things and privacy, as well as smartphones and the planet. Free to download, open-source and with no personal data collected, the *ePoc* application features a wide range of entertaining content including videos, podcasts, graphics and interactive activities. What better way to encourage people to learn more about the digital world?





## MAKING LEARNING ABOUT DEBUGGING MORE FUN

*If you want to be able to program and debug, you need to be able to picture the way in which a computer carries out instructions and memorises information.*

Seeking to help students to build this “notional machine”, the exploratory action AI4HI helped to develop Easytracker, a library that facilitates access to the internal states of programs written in Python or C. Examples of situations where this library could be used include during lectures, combined with a graphic interface. It is also central to Agdbentures, a video game that provides an autonomous and fun way to learn how to debug.

## A COLLABORATIVE PROJECT AIMED AT MAKING TEACHING MATHS EASIER

*LiberAbaci, a project launched in September 2022, is seeking to use the Coq interactive proof assistant to assist with the teaching of mathematics, particularly in the first years of university. Their aim is to collaborate with maths teachers in order to identify ways of bringing computer language closer to the standard language of mathematics, harnessing automation and IT for use in teaching, and creating environments that are conducive to learning. In doing so, they are hoping to be able to make improvements to Coq, thereby helping students.*



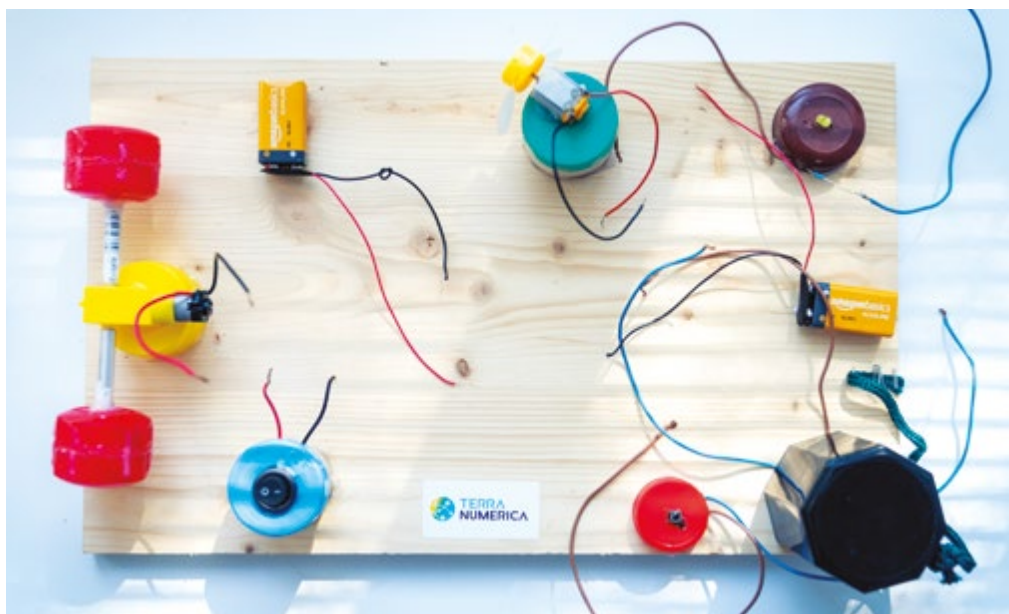




## OUR INITIATIVES

### Partnerships: establishing ties through scientific outreach

**It's been a busy year for scientific outreach, from the creation of new partnerships and the strengthening of existing partnerships to the opening of a space dedicated specifically to it.**



#### A FLAGSHIP SPACE

When it comes to scientific outreach, Inria's scope of activity is vast... and it's only getting bigger. 2022 saw the opening of Terra Numerica, a flagship space for spreading the culture of digital science. Located in Valbonne in the Alpes-Maritimes department, it is the result of a collaboration between local authorities, the Nice regional education authority, Inria, the CNRS, Côte d'Azur University and local associations.

Measuring nearly 5,400 square feet, the space offers original and fun educational workshops, giving people an opportunity to discover and experiment with digital science. On top of this, scientific outreach also takes to the road throughout the region. *"There aren't enough spaces dedicated to digital science in France,"* explains Christine Leininger, *"making this a major project for scientific outreach on the subject."* The space meets a need for greater understanding of digital science among wider society, in addition to appealing to young people.

#### STRENGTHENING EXISTING COLLABORATIONS AND CREATING NEW ONES

This was one of the objectives of the partnership created in 2017 linking scientific outreach and the association Animath in the form of *Rendez-vous des Jeunes Mathématiciennes et Informaticiennes* (RJMI - Get-togethers for Young Female Mathematicians and Computer Scientists). Over two to three days, female secondary school pupils with

an interest in science are given the opportunity to meet Inria researchers and ask them any questions they might have.

*"Scientific outreach is a dialogue between researchers and society. In addition to popularisation and information-sharing, public engagement and participation is also necessary,"* explains Christine Leininger, head of the scientific outreach project. *"Three centres were involved in the initiative in 2022, and we're hoping to see that number rise,"* adds Corinne Touati, researcher and scientific outreach task officer.

#### TWO NEW PARTNERSHIPS

Corinne Touati heads up the national scientific outreach unit at Inria, which liaises with the Communication and Mediation Department and correspondent researchers at each centre. Together, they provide support and turnkey tools to scientists looking to engage in scientific outreach. The toolkit was expanded with the creation of two new partnerships in 2022. One, with the platform *l'Esprit Sorcier*, will see the production of three programmes a year, in addition to short programmes on Inria research. The other, with the cooperative *Déb'Acteur*, is aimed at organising citizens' debates on the impact of science on society. The first of these, held at the *Fête de la Science 2022* (which focused on climate change) was on the topic of digital sobriety.



A person's hand is visible on the right side, pointing towards a large digital display. The display shows a complex interface with multiple charts, graphs, and data visualizations. The background is slightly blurred, showing what appears to be a modern office or meeting room with large windows. The overall tone is professional and focused on data analysis.

# Using digital reliability of information and services





## DECODING

### AI: developing reliable and ethical digital services for public administrations

**Providing French citizens with ever more effective and reliable digital services, while ensuring secure data processing, is a key consideration. We caught up with Kim Montalibet, data scientist and data science project coach within the Etalab department of France's interministerial directorate for digital, to discuss how public administrations have been evolving in response to the rise of artificial intelligence.**

#### **KIM MONTALIBET,**

*data scientist and data science project coach within the Etalab department of France's interministerial directorate for digital*



**Digital technology, and specifically artificial intelligence, is becoming ever more prominent in public administrations. Public administrations have shown a growing interest in the development of dedicated digital tools and services in recent years, irrespective of their level of maturity on such issues.**

Their aim is to meet the needs of staff by developing digital tools with the capacity to improve efficiency at work. AI and data science tools can be used to automate low value-added tasks, for example, or to provide decision-support tools. A good example is the large-scale processing of administrative documents, an issue for many public administrations, or natural language processing, which makes search engines smarter and makes it easier to find more specific information in documents.

But there remain a number of obstacles that will need to be overcome. HR is faced with the difficult task of recruiting the right profiles and integrating them in order to implement digital transformation projects long-term. The appeal of the public sector is also a key issue.

Another potential stumbling block is the data culture in France. High-quality data is needed if we are to develop advanced AI projects. Some ministries might find they are unable to follow through on projects, unable to get their hands on the external data they need. It is vital that we spread the word about data sharing and open data.

Finally, when working with AI it is essential to ensure that there is no ethical bias and that there is transparency when it comes to the way in which algorithms are designed and used. This is something we really need to focus on, particularly given the upcoming EU regulation on AI, the AI Act, which was first proposed in April 2021 and which is set to become law in 2025. The AI Act will regulate the use of AI in accordance with the severity of the risk, with safeguards adapted to each level of risk.

Between 2019 and 2022 we supported 26 AI projects in the public sphere, in justice, security, economics, health, food and the ecological transition. Our partnership with Inria means we have been able to bring in leading researchers to develop algorithms which address all of the issues faced by public administrations.

## OUR ACHIEVEMENTS 2022



### CEDAR - GOING STRAIGHT TO THE SOURCE

When it comes to verifying all of the information that appears in the traditional media, on social media or quotes from politicians, journalists need help. Fortunately, Cedar, a team at the Inria Saclay centre (a joint undertaking with the École Polytechnique), has come to the rescue. Their first project, *ContentCheck*, which the French National Research Agency (ANR) funded between 2016 and 2019, brought the researchers together with the fact checkers from *Le Monde*. 2022 saw the launch of *SourcesSay*, another partnership between Inria, the École Polytechnique and Radio France that is supported by the ANR-DGA Chair in AI. The aim of this partnership is to develop software capable of quick and easy fact-checking of statistics, using reliable databases like the one developed by INSEE, in addition to creating sets of verified, sourced proofs on controversial subjects. Quite the undertaking...

### REVAMPING THE TAX CALCULATOR

Capable of processing around 650 households a second, France's national household tax calculator is a high-performance piece of software architecture, but it was developed back in the 1990s. Between changes to laws and technological developments, it was long overdue for a reboot. Researchers, including Denis Merigoux from the Prosecco project team at the Inria Paris centre, were given authorisation to access the source code for the tax calculator, and were able to develop *Mlang*, a new compiler based on *Ocaml*, the opensource language created by Inria. More reliable and with new features, this will soon be incorporated into the tax calculator.

### AI USED AT THE COURT OF CASSATION

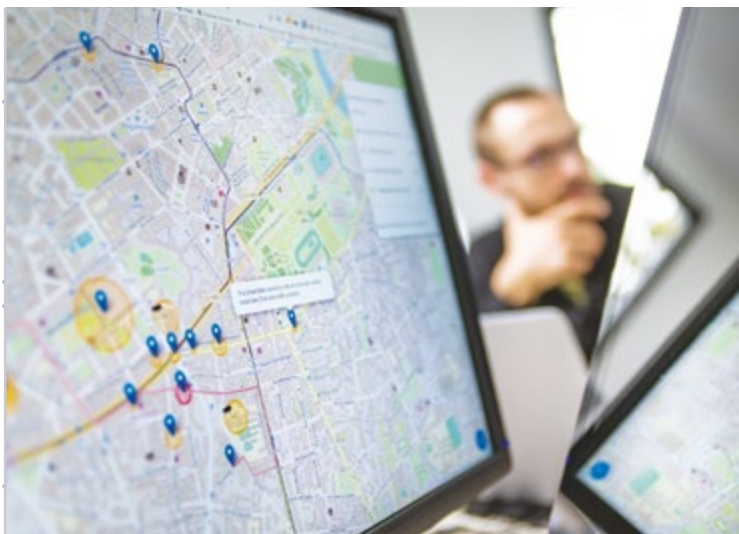
Comparing court rulings to ensure that the law is applied in the same way across the board is a mammoth endeavour. The Almanach project team at the Inria Paris centre thought they might be able to help the Court of Cassation in this task through Lab IA, which enables public institutions to collaborate with Inria researchers. They used AI to automatically attribute titles to court rulings based on their summaries. This makes it easier to identify similar documents, allowing them to identify any divergences.



FACT CHECKINGS

FINANCE

JUSTICE



## REGALIA - SEEKING OUT BIAS

*Regalia (Régulation des algorithmes d'IA - Regulation of AI Algorithms) is the name of a pilot project that Inria has been running since 2020. The aim of this project is to identify any bias in algorithms (e.g. pricing or recommendation algorithms) used by major platforms and to help them to regulate them. Not only did Regalia's researchers play a part in developing the regulatory framework for this at an EU level, but they also provided the regulatory authorities with unintrusive methodologies and good practices for evaluating the compliance of platforms' algorithms. A library of audits of black box algorithms (featuring just the results of algorithms, and not their computer code) is now operational, and has already been used with food delivery companies and travel comparison websites. This year has also seen the launch of two PhDs on algorithm loyalty, in partnership with other Inria teams.*

## ELIMINATING THE GENDER PAY GAP

*According to INSEE, women earn 24% less than men. Seeking to ensure "equal work for equal pay", EquityAnalytics, a project led by Petra Isenberg at Inria Saclay, is using visual analysis to explore the issue of equal pay. In concrete terms, this involves analysing existing bias in the visualisation of data used for decision-making in payment systems, the goal being to develop a better understanding of them. EquityAnalytics is being run in collaboration with PayAnalytics, an Icelandic company that provides businesses with an equal pay software platform to help them close the pay gap between employees.*

## MONITORING ALGORITHMS WITH SKYLD

*How can the security of algorithms on mobile phones or connected objects be ensured? How can companies make sure that competitors don't get their hands on them? These are the sorts of questions that SkyLd, a startup incubated at Inria Startup Studio, is looking to find answers to. Drawing on the use of cryptography, their aim is to protect algorithms and the data they gather, with an algorithm execution time below 300 milliseconds to deliver a real-time response. The company has already developed a demonstrator and a proof of concept, which it is currently seeking to deploy.*







## OUR INITIATIVES

### Digital transformation and continuous improvement at Inria: the DSI and DOT working hand-in-hand

What can be done to streamline the internal operations of a research institute? This is the focus of the partnership between the DSI (the IT department) and the DOT (the organisation and transformation directorate). Working together, their aim is not only to develop the digital tools used by agents, but also to help them to work more efficiently, identifying speedy, pragmatic solutions to everyday problems.

**FLORIAN DUFOUR,**  
Director of Information Systems  
at Inria



Before anything can be done, however, the DOT must first carry out a process review: *"This is a difficult task, which involves getting the relevant departments to take a step back, to forget their current practices and to come up with something more efficient, where appropriate"*, explains Philippe Henry, director of organisation and transformation at Inria.

Once the new business process has been identified and approved by the stakeholders concerned, the IT department can then launch a project to create new tools or improve existing tools suited to this new way of doing things. *"You can't deploy new tools without first considering business processes. It just doesn't work. Tools have an initial philosophy, and you need to make sure that they are compatible with our ways of working"*, explains Florian Dufour, head of Inria's IT department.

**PHILIPPE HENRY,**  
Director of Organisation  
and Transformation at Inria



The DOT then picks up the baton to handle maintenance of the process over time, taking care of documentation and ensuring effective implementation throughout the institute. *"There is a significant organisational component to the digital transformation of the institute. Introducing major changes means questioning ways of working - this is our responsibility, supporting different lines of business within the institute"*, explains Philippe Henry.

#### A MORE GLOBAL DYNAMIC, BASED ON USER FEEDBACK

A few months ago, Inria launched a "continuous improvement initiative", drawing initially on the 2023 action plan. Centred around 20 main areas of focus, the main aim of this initiative is to identify speedy, pragmatic solutions to everyday problems.

*"This is a long-term dynamic, but one that is seeking immediate results across all business lines within the institute. The aim is to address issues faced by staff across the institute in their day-to-day work"*, explains Philippe Henry. *"The long-term goal is to deploy a bottom-up approach that sees staff playing an active role in the process of improving their working conditions."*



## PORTRAITS

### When mathematics meets machine learning

**At Inria, a number of researchers have a precise grasp of the mathematical concepts behind machine learning. Discover the portraits of four of them, whose year 2022 has been marked by outstanding results and awards.**

#### ÉMILIE CHOUZENOUX ①

Optimising the processing of medical data

For Émilie Chouzenoux, 2022 saw the publication of several major results with the team working on the ERC project MAJORIS, highlighting strong links between optimisation and the related fields of statistics and machine learning. In a context such as applied medicine, results must be both interpretable and quantified. Bayesian inference provides one way of tackling this problem, employing digital methods such as Monte Carlo sampling. The issue here, however, is that such methods can be highly complex to implement and slow to execute. In 2022 the MAJORIS project team made great strides in overcoming these obstacles, developing high-performance Bayesian inference algorithms incorporating advanced optimisation techniques and AI tools. The methods deployed are both quick and easy to implement, in addition to being quick to run on a GPU, and should help pave the way for effective integration of trusted AI in the medical sphere.

#### BIOGRAPHY

*Having been an Assistant Professor at Paris-Est University Marne-La-Vallée from 2011 to 2019, Émilie Chouzenoux is now head of OPIS, a project team specialising in the analysis and processing of masses of complex data from the medical sector. In 2020 she was awarded an ERC Starting Grant for her project MAJORIS. Her research focuses on the next generation of optimisation algorithms, which possess the requisite flexibility, reliability and speed to tackle the acquisition, processing and optimisation of biomedical data.*

#### FRANCIS BACH ②

Splitting time between optimisation and machine learning

Most modern machine learning methods are formulated as optimisation problems, where the aim is to minimise the number of errors committed by a model on training data. For 40 years this has led to the use of generic optimisation algorithms, in addition to developments specific to machine learning. Alessandro Rudi, Francis Bach and their PhD students and post-doctoral researchers have spent the past three years seeking to utilise statistical methods derived from machine learning within so-called “sum-of-squares” optimisation algorithms, with applications in statistics and control theory. This research was presented at the International Council for Industrial and Applied Mathematics (ICIAM) Congress in Tokyo in August 2023, a major conference in applied mathematics that is held every four years.

#### BIOGRAPHY

*Francis Bach is head of the SIERRA project team, a joint undertaking involving Inria, the CNRS and the Computer Science Department at the École Normale Supérieure. His main area of focus is machine learning, with a particular emphasis on optimisation algorithms. He was made a member of the French Academy of Sciences in 2020.*



## JULIEN MAIRAL ③

Winner of a prestigious ERC Consolidator Grant

Having previously been awarded an ERC Starting Grant in 2016 for his project SOLARIS, Julien Mairal was to receive a further award in 2022, this time in the shape of an ERC Consolidator Grant. The aim of his project, Apeleia, a name which refers to a relatively obscure divinity said to personify simplicity, is to encode a number of constraints into learning algorithms, which the models being taught must adhere to for each individual problem. These constraints may come from physics or biology, for example, depending on the application. The project will also seek to understand how to reduce the size of machine learning models, drawing on the principles of simple mathematics. The multidisciplinary component of the project is important, and is designed to have a lasting impact on different fields within science through collaborations, including image processing, astrophysics, and remote sensing.

### BIOGRAPHY

*Julien Mairal has spent more than a decade studying machine learning and its applications in artificial vision and image processing. He first came across the subject during his PhD at ENS Paris and Inria between 2007 and 2010, with further study during a two-year postdoctoral fellowship at the University of Berkeley in California. Julien then went on to join Inria permanently in 2012 as a researcher at the Inria centre in Grenoble. Since 2018 he has headed up Thoth, a project team dealing with machine learning and computer vision.*

## RÉMI GRIBONVAL ④

“Parsimony will be of great value in the future”

2022 saw great strides being made in research into parsimonious neural networks, thanks to the work carried out by the Ockham project team as part of Rémi Gribonval's AllegroAssai AI Chair. A series of papers demonstrated the fundamental properties of the quantification of deep networks, in addition to highlighting the surprising phenomenon of instability in certain problems linked to the optimisation of parsimonious networks. These theoretical results provided the seeds which, in 2023, grew into algorithms with the real potential to improve both the compression and the efficacy of neural networks.

### BIOGRAPHY

*After spending around twenty years or so with the PANAMA project team at the IRISA studying audio signal processing, Rémi Gribonval came to Lyon in 2019 to explore the mathematical side of machine learning. The researcher, winner of an ERC Starting Grant in 2011 in addition to being an IEEE and EURASIP fellow, is currently in charge of the AllegroAssai AI Chair and head scientist for the Inria project team Ockham at the ENS de Lyon. He is also head of Sharp, a priority AI research project (PEPR IA) exploring the principles of frugal AI, which is set to begin in late 2023.*



# INRIA FOUNDATION

## 2022 - a year of intense development for the Inria Foundation

**The Inria Foundation aims to mobilise new financial resources to allow the Institute to support bold projects that make sense of the digital world. We caught up with Nelly Haudegand, the Foundation's new CEO, to discuss changes to its development strategy over the past year.**

### YOU'VE BEEN HEAD OF THE INRIA FOUNDATION SINCE JANUARY 2022: WHAT IS ITS PURPOSE AND WHAT ARE ITS CURRENT OBJECTIVES?

As the development of digital technology continues apace, the Inria Foundation is seeking to help to put a human face on the digital transformation. Working with the world of academia, businesses and civil society, our aim is to build programmes with the capacity to make an impact and to correct the harmful effects of digital, in addition to increasing its potential for inclusion, autonomy and protection for people, society and the planet. Combining research & development, training, education, scientific outreach and awareness-raising - and even advocacy - these programmes target four fields in which digital is a critical lever: health, the environment, education and the society of trust.

### HOW DO YOU LOOK BACK ON YOUR FIRST YEAR IN CHARGE OF THE INRIA FOUNDATION?

When I joined the Inria Foundation I was tasked with accelerating its development. In recent months we have worked intensely with Inria staff - who I would like to thank - to decide on the positioning of the Foundation and its operating strategy, identifying programmes at the intersection between societal issues, concerns affecting businesses and solutions from research. We have determined operating modes - including the compensation system, internal processes, and so on - and created engagement tools, including a website, presentations, elevator pitches

and project maps. We have had extensive dialogue with the ecosystem and with around twenty or so companies outside of Inria's natural sphere of influence, in fields such as insurance, banking and health. For these companies our foundation is a go between with the capacity to streamline relations with research teams.

### WHAT TOPICS DO YOU SEE FUTURE BIG IMPACT PROGRAMMES FOCUSING ON?

The first thing that comes to mind is our environmental concerns, and the "AI FOR IS.0" programme. Inria is well-placed when it comes to tackling the research challenges raised by Industry 5.0 and helping to make industry virtuous and environmentally responsible. The Institute has a long tradition of working with industrial partners, growing engagement with environmental issues on the part of researchers, and excellence in areas such as robotics, human-computer interfaces, modelling, simulation, optimisation, digital twins, networks and so on. Education is another major issue for us, and with support from the government and a number of partners we are currently incubating two projects which we really believe in: *Horizons numériques* (Digital Horizons) and *10 000 TechTudiants* (10,000 Tech Students). Tying all of this together is a desire for greater access to digital training, whether for women, who are notoriously under-represented in this field, or for groups who have fallen victim to the urban/rural divide and who have struggled to access study.

### A SPONSORSHIP AGREEMENT TO SUPPORT THE DIGITAL TRANSFORMATION IN THE CORPORATE WORLD

*"In March 2021 Inria, the Inria Foundation and La Poste (the French post office) signed a three-year sponsorship agreement. The growing digitisation of both the economy and society has had a massive impact on La Poste. They reached out to the Inria Foundation for support with their digital transformation, seeking to incorporate three pillars of their corporate strategy: the environment, trust and health. We provided significant support for the FedMalin challenge, the aim of which was to drive forward research into federated learning."*

Nelly Haudegand, CEO of the Inria Foundation

*"A positive dynamic is underway. Our Group has helped to fund seven projects and two PhDs, as well as the recruitment of nine engineers and postdoctoral researchers. We are very excited about what 2023 has in store: in addition to new research initiatives, 2023 will also see the launch by the Foundation of two initiatives with major societal impact. Our partnership is making a real difference. The teams are familiar with each other and have a clearer picture of subjects they might be able to work on together - two key aspects if we are to meet our shared goals."*

Fatiha Gas, head of innovation at La Poste

# THE DEFENSE AND SECURITY MISSION

## Inria expertise put to use for defence and security

Created in 2020 as part of Inria's Objectives and Performance Contract (OPC), the aim of the Security and Defence Mission is to pool together and develop all of Inria's initiatives with the capacity to meet strategic national needs in these areas in the digital sphere. We caught up with Frédérique Segond, who heads up the mission, to look back on what was a particularly fruitful year.



### WHAT IS THE ROLE OF THE SECURITY AND DEFENCE MISSION?

The mission was set up in response to one of the four main areas of focus outlined in the OPC which Inria signed with the government in 2019: to support public policies aimed at promoting France's digital autonomy and sovereignty. Inria provides its expertise in support of the needs of the Ministry of Armed Forces and the Ministry of the Interior. The team for the mission is split across sites in Paris, Grenoble, Rennes and Montpellier, and is comprised of around a dozen or so individuals with cross-disciplinary skills in research, engineering, business, and so on.

From consulting and expertise, technology transfer to ministries or defence companies, and participation in collaborative projects, to supporting company creation and staff training, we provide support in a range of areas, meeting the diverse digital needs of the armed forces.

### HOW DOES THE MISSION OPERATE AND WHAT WERE SOME HIGHLIGHTS FROM 2022?

We gave fresh impetus to strategic partnerships Inria had signed with industrial and academic stakeholders in the defence sector, including Naval Group, Atos and the ONERA. We renewed our partnership with the Ministry of Armed Forces and held discussions with senior military staff aimed at devising a roadmap that would meet the needs of the armed forces. All of these initiatives now fall under the same umbrella from a governance perspective.

Lastly, we are currently introducing new ways of working: this includes building shared laboratories on subjects of interest such as intelligence, and introducing an agency for defence-oriented projects with the CEA (the French Alternative Energies and Atomic Energy Commission). We have also sought to secure Inria's position as a stakeholder

in the security/defence sector vis-a-vis R&D funding organisations. These activities are the foundations on which the mission will be established long-term at each individual Inria centre, within a governance structure shared with the Ministry of Armed Forces, in addition to developing our relationship with the Ministry of the Interior.

### WHAT PROJECTS DO YOU FEEL ARE REPRESENTATIVE OF THE WORK CARRIED OUT BY THE MISSION?

*Intel Lab* is one of our success stories from the past few years: using "serious games", this digital platform, developed in collaboration with the French Directorate of Military Intelligence, enables us to raise awareness of the intelligence sector within the world of research (both academic and industrial), the goal being to devise and experiment with technology that could be of use to them. As part of the EICACS (European Initiative for Collaborative Air Combat Standardisation), an EU project coordinated by Dassault Systèmes, Inria's expertise came to the fore in our recommendations on the EU's sovereignty with regard to AI algorithms. We are also contributing to two other projects, *CLEE* (*Carburants Liquides à Energie Elevée* - High-Energy Liquid Fuels) and *CAMPAIGN* (*Campagnes informAtionnelles Multimodales: imPAct, Identification, profilaGe et caractérisation* - Multimodal Information Campaigns: Impact, Identification, Profiling and Characterisation), funded by France's Defence Innovation Agency. Here we have drawn on Inria's expertise in the field of AI, helping to develop new fuels and detect manipulation on social media. Lastly there is the *Indago* system for the monitoring of communication networks. Developed by the MASSAI project team, it is currently in the process of being integrated into a department within the upper echelons of the military.

# Annual Report



## ANNUAL BUDGET REPORT FOR THE 2022 FINANCIAL YEAR

Inria's initial budget for 2022, which was voted on in December 2021, was €312.1 million for resources and €320.8 million for expenses.

With regard to the execution of the 2022 budget and in terms of income, the **Public Service Grant** stood at €186 million, compared to €178 million in 2020 and €189.7 million in 2021. It represents 72% of the revenues received for the 2022 financial year.

**Own resources** amounted to €73m, an execution rate of 86% in relation to the amounts posted in the last amending budget. They accounted for 28% of all of the institute's resources in 2022. Own resources mainly come from:

- Research contracts with third parties in the private or public sectors: €9.5m
- Research project and programme subsidies: €47.1m
- Services: €13.9m
- Product sales: publications, conferences, etc.: €1m
- Financial transactions related to fixed assets: €0.0023m

Incl.: €15.8 million from the ANR (the French National Research Agency), €32.36 million from other public partners €9.66 million from the European Commission and €14.68 million from private partners.

**Total revenue** was €258.5m in 2022, representing an execution rate of 96% in relation to the amending budget.

**By nature**, expenditure breaks down as follows: €197.5m in payroll costs (76 % of total expenditure), including €146.3m for the Restrictive Wage Bill and €51.2m for the Non-Restrictive Wage Bill.

The number of "under the ceiling" staff (i.e. those whose pay is based on the Public Service Grant) reached 1,554.1 full-time equivalent hours worked (FTEHW) compared to 1,604.5 in 2020 and 1,516.6 in 2021. 1,680 was the forecast in the initial budget for 2022. The number of "non-ceiling" staff (i.e. those whose pay is based on own resources) was 1,090.1 FTEHW compared to 848.6 in 2020 and 1,091.8 in 2021.

- €57.2m for non-scheduled investment and operating costs;
- €5.2m in expenditure related to scheduled investment transactions.

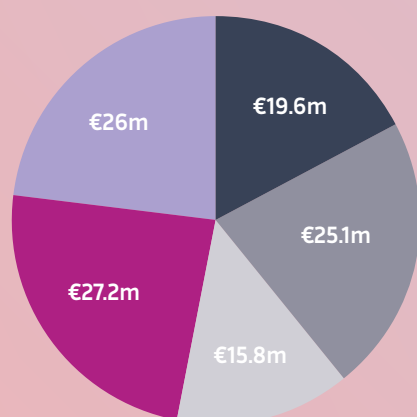
Total expenses for 2022 were €259.9m, representing an execution rate of 88% in relation to the amending budget.

**By purpose**, expenditure in 2022 included:

- €167.8m on scientific activities at research centres (item 1), 65% of total expenditure in 2022
- €25.5m on joint research activity (item 2), i.e. 10%
- €66.6m on support functions (item 3), i.e. 25%

The table below shows the scientific themes corresponding to the institute's main objectives, taking all expenses into account, regardless of funding source and all items combined.

### TEAM EXPENSES PER SUBJECT



€113.7m

- Applied Mathematics, Computing and Simulation
- Algorithms, Programming, Software and Architecture
- Networks, Systems and Services, Distributed Computing
- Perception, Cognition and Interaction
- Digital Health, Biology and Planet

# Services

## 10 KEY FIGURES ON INRIA

9

Inria centres in France  
within major  
research universities

103

Deeptech start-up projects  
supported since 2019

220

project teams, 86%  
of which are joint undertakings  
with our partners

16

strategic international  
partnerships signed  
since 2019

4,750

scientists and research  
support staff (including  
2,800 paid by Inria)

7

PEPR (priority research  
programmes) co-coordinated  
by Inria including  
3 Exploratory PEPRs

Nearly  
2,000

scientific papers  
published in 2022

€260

million euro budget  
executed in 2022

38

exploratory projects  
launched in 2022

Inria,  
1<sup>st</sup>

recipient of ERC grants  
from the European Union  
in the digital field



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**COMMUNICATION DIRECTOR**

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